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A COMPUTER PROGRAM FOR THE AVOIDANCE OF HYDROGEN CRACKING

FINAL REPORT

BY

SANTAROSSA TRADING COMPANY LIMITED

Work on this project was conducted under the auspices of Physical Metallurgy Research Laboratories Canada Centre for Mineral and Energy Technology Energy, Mines and Resources Canada

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SUMMARY

Due to the recent miniaturization of computers and their relatively low cost and size of memory it has been the norm for most small companies to purchase such personal computers for every day accounting and engineering usage. With this in mind, it was proposed that a program be divised which would assist the small fabricator which cannot afford the services of a part time specialist in the field of welding.

The program proposed would evaluate the user/fabricator welding procedure variables and give data which would indicate the minimum welding variables which preclude hydrogen cracking. Hydrogen cracking is a most insiduous welding defect which can go undetected even with todays sophisticated nondestructive testing methods.

The program would be user friendly and would be affordable to the smaller fabricator such that usage of the program would be encouraged with the end result of fewer weld defects. This of course results in savings to the fabricator in the form of fewer weld repairs and provides the puchaser of the weldment with a safer project.

INTRODUCTION

The objective was to determine the technology required to generate a computer program which would evaluate a small fabricators weld procedure and then to devise the program.

Existing industry codes such as ANSI B31.1 and B31.3 (American National Standards Codes for Pressure Piping - Power Piping and Chemical Plant and Petroleum Refinery Piping, respectively), ASME Section VIII - Division I (American Society of Mechanical Engineers Boiler and Pressure Vessel Code), CSA Z183 and Z184 (Canadian Standards Association for Oil Pipeline Transportation and Gas Pipeline Transportation, respectively) and BS 5135 (British Standards Institution for Metal Arc Welding of Carbon and Carbon Manganese Steels) were consulted upon for the appropriate technology. Only the BS 5135 contained any proven and detailed approach to solving the technological evaluation requirements.

Hydrogen cracking in the opinion of the writer, is one of the most difficult weld defects to deal with in the welding of carbon and carbon manganese steels. The reason for this is that hydrogen once introduced into the molten weld pool under the correct conditions can lead to cracking. The cracking can have an incubation period of up to 72 hours which means that nondestructive testing can occur prior to the cracks developing. Alternatively, if the cracks are present prior to testing, they can be unseen depending upon the type of nondestructive testing method used and its sensitivity. In the case of radiography, chances are that the cracks will go undetected whereas, with ultrasonics, there is a good chance that the cracking can be detected. In practice radiography is used primarily because ultrasonics is very labour intensive and time consuming.

The Wang Personal Computer was selected to carry out the programming due to its speed and compatability in MS-DOS Basic with the IBM Personal Computer. The computer program was written in Basic and was devised to be extremely user friendly. The program used a multitude of menus to guide the user through the program evaluation of the welding procedure variables. The program features a "Help Menu" which provides the user at all steps of the program evaluation with the know how and background required to continue the use of the program. The end result is a listing of the minimum required variables to preclude hydrogen cracking. In addition, a user manual is provided for the guiding of the user in the operation of the program.

The technology available was utilized to produce the computer program to analyze user welding procedure variables for the avoidance of hydrogen cracking.

DESCRIPTION OF WORK

As mentioned previously, the literature was surveyed for the appropriate information which would allow the conception of the program. In addition to surveying the applicable industrial codes of practice, published data was used to devise explanations for the different features of the computer program. Also, individuals from regulatory agencies were invited to peruse the subject program and their comments were incorporated into the program logic.

Once the preliminary working data had been gathered, the actual program construction began. The program was devised such that a central program would marshall the user to the respective subroutines which would evaluate the user welding procedure variables one by one. This was accomplished by having the user input the exact variable to the computer by means of inputing statements. This makes the program interactive and the user involved with the programming.

The different subroutines not only quiz the user for the welding variables but provide the user with data to allow decision making as to which classification the respective user variable would fall under. For example, in the "Consumable Classification by Weld Deposit Hydrogen Content" menu, the user is asked under which of the scales listed his consumable falls. The help menu can be referred to by simply keying in "HELP" as an answer and the help menu is immediately provided to the user to consult in order that he may make the correct choice of scale. This was incorporated throughout the program as is discussed later.

After the program was devised, debugging was carried out in order to prevent any erroneous answers and inputs from reaching the actual computing segment of the program. Also to further simplify usage, a user manual was provided for guidance.

In summary, the appropriate literature was used in the programming and construction of the computer program and user manual in order than an easy to use and understand program and guide would result.

DISCUSSION

The program begins by providing the user with a main menu to select the program mode which suits the users particular requirements. The main menu allows the user to go directly to the calculations segment, to the help segment or the explanation segments which describe what hydrogen cracking is and how it can be controlled by means of welding variables.

The calculations segment contains a subroutine which informs the user as to which welding variables and units for the variables will be required. After the explanation, the actual calculation begins with the carbon equivalent segment of the program.

This segment is comprised of a section which explains the formula to be used and the data required. If the data is not available to the user the help menu can be consulted to provide a library of chemistries for materials which can be used in the program. Once the entering of the chemistries as directed by the program is complete, the user can proceed to the next evaluation phase which is the weld deposit hydrogen content segment.

This subroutine asks the user to classify the welding consumables he plans to use by means of a scale based upon the amount of hydrogen expected in the weld deposit. Again the help menu provides direction in the form of published data for different types of consumables.

The next programming step is the classification of the joint to be welded. The user is asked to select a fillet or butt type of joint. Also if the process is shielded metal arc, the user is also asked what type of electrode he will be using in the welding procedure. After these inputs have been made by the user, the program proceeds to the next segment of the program which is the arc energy calculation.

This subroutine asks the user to input the voltage, current and weld speeds to be used in the welding procedure. The program then makes a heat input calculation and then proceeds to the next program segment which is the combined thickness calculation.

Based upon the type of joint which the user had previously input, the thicknesses of the metal to be welded are asked of the user. A calculation of combined thickness is then made by the program.

With the data as aforementioned, the program then starts to make the preheat calculation. This is accomplished by using the user inputs and inserting these inputs into the library subroutines which contain published data from BS 5135 in the form of tables and graphs. The tables and graphs were input as random files in order to economize on storage space and speed of retrieval.

In essence the program consults upon graphs which have been stored as formulae devised by linear regression. The appropriate graph is selected by knowing the correct hydrogen scale and carbon equivalent. The minimum preheat is selected by knowing the combined thickness and arc energy heat input. Then based upon a minimum required heat input, the program consults upon the stored tables in order to select a required electrode runout length for a given electrode diameter to satisfy the given user variables.

In addition, a final table is consulted upon in the case of fillet welds to provide the user with minimum weld sizes for a given heat input and weld electrode.

The help menu portion of the main program was devised to be of assistance to the user for technical details which would permit the user to run the program and not be constantly surveying the literature for information.

Features of the help menu include the following:

1. Chemical Compositions Menu - The menu lists most of the industrially used carbon and carbon manganese steels which would be applicable to the subject program and their compositions for entry into the carbon equivalent formula.

2. Consumable Weld Deposit Hydrogen Content - This subroutine lists the hydrogen contents to be expected in the weld metal after observing certain storage precautions for the various consumables. This permits the user to make the correct scale choice.

3. Preheating Considerations - This subroutine informs the user of the logistics of preheating once a recommended preheat has been provided by the program.

4. Fit-Up Considerations - This subroutine provides the user with logistical data which can influence the avoidance of hydrogen cracking.

5. Solidification Cracking Considerations - This subroutine informs the user on the danger of using too much preheat to preclude hydrogen cracking.

6. Notch Toughness Considerations - This subroutine informs the user of the pros and cons of preheating as applied to obtaining low temperature notch toughness properties in a weldment.

7. Joint Restraint - This subroutine warns the user of the limitations of the program to deal with extremely high joint restraint situations.

8. Preheat Relaxations - This subroutine informs the user about relaxations in preheat with the appropriate proviso.

9. Main Menu - This selection allows the user to return to the main menu for selection of the desired program feature.

In addition, the user can return to the program segment after consulting upon the help menu rather than having to start all over and the user can also refer to previous screens rather than having to reinitiate the subroutine by returning to the help menu. The user can also exit a subroutine and return to the help menu without having to survey the total subroutine information presented on the monitor.

The explanation segments of the program explain what hydrogen cracking is and how it can be avoided. The user can then return to the main menu for selections other than those of an explanatory nature.

A user manual which describes the different screens and how to utilize them is provided in Appendix A. The manual is a step by step description of what will flash up in front of the user and what is to be done by the user in order to continue with the program.

CONCLUSIONS

It was concluded that a user friendly computer program could be devised such that a small fabricator could use the computer program to evaluate his welding variables. It is recommended that future programs of this type be devised dealing with other such topics which would benefit the smaller fabricator such that expensive specialists need not be consulted upon.

It has been a pleasure working for the Department of Supply and Services on behalf of Energy, Mines and Resources. I have included in Appendix B my final billing and I hope this meets with your approval. I have included copies of the computer program for the Departments use as well as a copy of the program in Appendix C.

If you have any queries please feel free to contact me at my present place of employment:

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I look forward to hearing from you in the future.

Yours truly,

SANTAROSSA TRADING COMPANY LIMITED

Per: Robert A. Santarossa

Robert A. Santarossa, P.Eng.

APPENDIX A

USER MANUAL FOR
THE
COMPUTER PROGRAM FOR THE AVOIDANCE
OF HYDROGEN CRACKING

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SYSTEM NARRATIVE

The Computer Program for the Avoidance of Hydrogen Cracking is an interactive/online system which provides information about welding variables and their effect on the susceptibility of a carbon or carbon manganese steel to hydrogen cracking. Information is input into the program by the user as prompted by the program. This information is then used by the program to calculate a preheat value, electrode run out length and minimum leg length (in the case of fillet welds) to preclude hydrogen cracking. There are screens which permit the user to input the welding variables he plans to use. A step approach is used to go through the data required for the program in an organized and speedy manner.

Three main screens exist for operating the program. A main menu which sends the user to either informational screens, help screens or calculation screens.

OPERATING PROCEDURES

Signing on the System

The following is an example using the Wang PC computer and operating system to sign onto the system:

1. Start system with the System Software diskette correctly inserted in Drive A.

2. After the power on diagnostic indicator lights are extinguished and the start-up screen indicates the system has been brought up from Drive A, press the "EXECUTE" key to proceed from the Date and Time screen to the Main System Menu.

3. Move the acceptance block to the Program Development menu selection on the Main System Menu and press the "EXECUTE" key. The Program Development menu appears on the screen.

4. On the Program Development menu, move the acceptance block next to the "OTHER" selection and type in the line provided "B:BASIC.EXE" and press the "EXECUTE" key.

5. The BASIC display appears on the screen and then type in an open area on the screen "LOAD PROG.BAS, R" and press the "EXECUTE" key.

6. The program will then show the title screen and will after a five second lapse, display the Main Menu.

Signing off the System

To disrupt program execution at any time or to exit the program simply press the "SHIFT" and "CANCEL" keys and the program will be disengaged. Next to return to the Program Development Menu type "SYSTEM" in a free area of the screen followed by depressing the "EXECUTE" key and control to the System Software diskette will be returned.

GENERAL CONVENTIONS USED IN THE SYSTEM

ACTION	RESULT
Hit "RETURN" without specifying a selection criteria, or input	Your input will be considered = 0 (null)
Hit "RETURN" with or without specifying a criteria	You will proceed to the next desired input or screen
Type in "PREV"	You will return to the previous screen.
Type in "HELP"	You will return to the Help menu
Type in "CC MENU"	You will return to the Chemical Compositions Menu
Type in an erroneous number or input	Error trapping will display an error message and return you to that same prompt

Selection Numbers: Selection numbers will always appear in a menu on the left side of the screen in braces < >. This is the number which must be entered when prompted with:

MENU selection? __

User Inputs: User inputs will always be prompted by a question and a flashing cursor on the right hand side of the question separated by a few spaces. Examples:

Next screen? __	Hit "RETURN" to proceed to next screen
Return to MENU? __	Hit "RETURN" to return to the Main Menu
%Carbon? __	Enter a number and hit "RETURN" to proceed to the next entry
?Redo from start (Y/N)_	Key in either "Y" or "N" and hit "RETURN" to proceed to the next entry

Screen Messages: Messages are always displayed on top of the input were the error occurred. If an error occurs, the screen will be redisplayed with the cursor positioned at the field in error with the previous errors displayed for reference.

HOW TO OPERATE THE SYSTEM

Type in the required input as requested by the program and press the "RETURN" key to enter the answer into the computer memory. For simple changes of screen, it is sufficient to hit the "RETURN" key.

SCREENS

a. Main Menu

FUNCTION	OPTION
General description of hydrogen cracking	1
Conditions for the avoidance of hydrogen cracking	2
Calculations and explanation of variables for the avoidance of hydrogen cracking	3
Calculation of variables for the avoidance of hydrogen cracking	4
Help MENU	5

PRESS EITHER 1, 2, 3, 4 OR 5 TO PROCEED TO THE DESIRED FUNCTIONS

1) From option 1, you will proceed to a two page narrative.
2) From option 2, you will proceed to a two page narrative.
3) From option 3, you will proceed to a two page narrative.
4) From option 4, you will proceed to a calculation menu.
5) From option 5, you will proceed to a menu consisting of narratives.

b. General Description of Hydrogen Cracking

This is a narrative consisting of two screens which describe what hydrogen cracking is. By keying in "HELP" the help menu will be immediately engaged. By keying in "PREV" on the second screen next to the "Return to MENU" prompt, the first screen will be redisplayed.

c. Conditions for the Avoidance of Hydrogen Cracking

This is a narrative consisting of two screens which describe how to avoid hydrogen cracking by means of welding procedure variables control. "HELP" and "PREV" features the same as in b.

d. Calculations Menu

FUNCTION	OPTION
Sequence of Calculations	1
Carbon Equivalent Definition	2
Carbon Equivalent Calculation	3
Weld Deposit Hydrogen Content	4
Type of Joint	5
Arc Energy Calculation	6
Combined Thickness Calculation	7
Recommended Preheat	8

PRESS EITHER 1, 2, 3, 4, 5, 6, 7 OR 8 TO PROCEED TO THE DESIRED FUNCTIONS.

1) From options 1 and 2, you will proceed to two page narratives.

2) From options 3 to 7 you will proceed to the calculation segment of the program.

3) From option 8, you will proceed to the preheat calculation segment of the program.

e. Sequence of Calculations

This is a narrative consisting of two screens which describe the welding variables required for inputs into the calculation segment of the computer program. This subroutine can be reached from option 3 of the main menu or option 1 of the calculations menu. By keying in "HELP" the help menu will be immediately engaged. By keying in "PREV" on the second screen next to the "Return to MENU" prompt, the first screen will be redisplayed.

f. Carbon Equivalent Definition

This is a narrative consisting of two screens which describe the inputs required for the calculation of the carbon equivalent number. Comments for "HELP" and "PREV" features are the same as in e.

g. Carbon Equivalent Calculation

FUNCTION	OPTION
Do you have the parent plate ladle analysis/ mill test certificates?	(Y/N)

PRESS EITHER "Y" OR "N" TO PROCEED WITH THE CALCULATION

1) From option "Y", you will proceed with the calculation.
2) From option "N", you will proceed directly to the Help menu.

FUNCTION	OPTION
ASTM, AISI, or API Designation?	Key in spec. title
%Carbon?	
%Manganese?	
%Chromium?	
%Molybdenum? etc. to %Copper?	Key in a number

PRESS "RETURN" AFTER EACH OPTION ENTRY

1) From the key in specification option, you will proceed to the narrative describing the inputing of the % compositions.
2) From keying in a number for the % composition, you will proceed to the next element and finally to the last element - Copper.

FUNCTION	OPTION
?Redo from start	(Y/N)

PRESS EITHER "Y" OR "N" TO PROCEED WITH PROGRAM EXECUTION

1) From option "Y", you will proceed to a new screen reinitiating the inputing process for the carbon equivalent calculation.
2) From option "N", you will proceed to the "Next screen?" prompt which will lead to the weld deposit hydrogen content screen.
3) Comments for "HELP" feature are the same as is in b.

h. Weld Deposit Hydrogen Content

FUNCTION	OPTION
more than 15 ml/100 g metal	1
not more than 15 ml/100 g metal but more than 10 ml/100 g metal	2
not more than 10 ml/100 g metal but more than 5 m/100 g metal	3
not more than 5 ml/100 g metal	4
FCAW, SAW and appropriate drying treatments	5

PRESS EITHER 1, 2, 3, 4, OR 5 TO PROCEED TO THE DESIRED FUNCTIONS

1) From options 1 to 4, you will have provided part of the data for the computer to select the appropriate preheat.
2) From option 5, you will proceed to the help menu.
3) Comments for "HELP" feature are the same as in in b.

i. Type of Joint

FUNCTION	OPTION
Fillet	1
Butt	2

PRESS EITHER 1 OR 2 TO PROCEED TO THE NEXT CALCULATION SEGMENT

1) From options 1 or 2, you will have provided part of the data for the computer to select the appropriate preheat.

FUNCTION	OPTION
Exx10, Exx12, Exx13, or Exx15	1
Exx14 or Exx18	2
Exx24	3
Exx28	4
None of the above listed	5

PRESS EITHER 1, 2, 3, 4 OR 5 TO PROCEED TO THE NEXT SCREEN

1) From options 1 to 5, you will have provided part of the data for the computer to select the appropriate preheat.
2) Comments for "HELP" feature are the same as is in b.

j. Arc Energy Calculation

FUNCTION	OPTION
Arc voltage	Key in a number
Welding current	Key in a number
Welding speed	Key in a number

PRESS "RETURN" AFTER EACH OPTION ENTRY

1) From keying in a number option for the arc voltage, welding current and welding speed, you will have provided part of the data for the computer to select the appropriate preheat.

FUNCTION	OPTION
?Redo from start	(Y/N)

PRESS EITHER "Y" OR "N" TO PROCEED WITH PROGRAM EXECUTION

1) From option "Y", you will proceed to a new screen reinitiating the inputing process for the arc energy calculation.
2) From option "N", you will proceed to the "Next screen?" prompt which will lead to the calculated arc energy value and to the "Next screen?" prompt for the combined thickness calculation screen.
3) Comments for "HELP" feature are the same as is in b.

k. Combined Thickness Calculation

FUNCTION	OPTION
T1	Key in a number
T2	Key in a number
T3	Key in a number

PRESS RETURN AFTER EACH OPTION ENTRY

1) From keying in a number options, you will have provided part of the data for the computer to select the appropriate preheat. T3 will only appear if the type of joint selected was a fillet. T1, T2, T3 represent the plate thicknesses to be welded to each other in mm.

FUNCTION	OPTION
?Redo from start	(Y/N)

PRESS EITHER "Y" OR "N" TO PROCEED WITH PROGRAM EXECUTION

1) From option "Y" you will proceed to a new screen reinitiating the inputing process for the combined thickness calculation.
2) From option "N" you will proceed to next prompt as follows.

FUNCTION	OPTION
Directly opposed twin fillet welds	(Y/N)

PRESS EITHER "Y" OR "N" TO PROCEED WITH PROGRAM EXECUTION

1) From options "Y" or "N" you will provide the computer with additional information to select the appropriate preheat.
2) Following the option selection, you will proceed to the "Next screen?" prompt which will lead to the calculated recommended preheat screen.
3) Comments for "HELP" feature are the same as is in b.

1. Recommended Preheat

1) This screen will list all of the user inputs and provide a calculated minimum preheat and interpass temperature for the user.
2) In addition, the maximum run out length for a given electrode diameter is also provided such that the correct heat input may be obtained so that the list of user inputs combined with the recommended preheat will preclude hydrogen cracking. Used in conjunction with codes of practice such as ANSI, ASME, CSA etc. the minimum value recommended by this computer program should not be less than the recommended value as provided in the code of practice which is usually 10 degrees celsius. A value of 0 degrees celsius requires that no preheat or minimum interpass temperature maintenance be used.

3) If the type of joint was a fillet, a second screen will be shown which provides the user with the required arc energy to produce the tabulated minimum leg length of the fillet weld. The given arc energy can be obtained from the previous screen by controlling the electrode run out lengths.

4) The "Main MENU?" prompt returns the user to the original starting screen for reusage of the program. See Operating Procedures for exiting the program.

m. Help Menu

FUNCTION	OPTION
Chemical Compositions for Carbon and Carbon Manganese Steels	1
Consumable Weld Deposit Hydrogen Content	2
Preheating Considerations	3
Fit-Up Considerations	4
Solidification Cracking Considerations	5
Notch Toughness Considerations	6
Joint Restraint	7
Preheat Relaxations	8
Main Menu	9

PRESS EITHER 1, 2, 3, 4, 5, 6, 7, 8 OR 9 TO PROCEED TO THE DESIRED FUNCTIONS

1) From option 1, you will proceed to the chemical compositions menu.
2) From options 2 to 8 you will proceed to narratives.
3) From option 9, you will proceed to the main menu.
4) You can always return to the chemical compositions menu by keying in "CC MENU" to the right of the "Next Screen?" prompt.
5) You can always return to the Help menu by keying in "HELP" to the right of the "Next Screen?" prompt.
6) You can aways return to the previous screen by keying in "PREV" to the right of the "Next Screen?" prompt.

n. Chemical Compositions for Carbon and Carbon Manganese Steels

FUNCTION	OPTION
Explanatory Notes	1
ASTM A27 - A135 Gr. B	2
ASTM A139 Gr. B - A334 CL.6	3
ASTM A350 - A516 Gr. 70	4

FUNCTION	OPTION
ASTM A524 TYP. I - A737 Gr. B	5
ASTM A737 Gr. C - AISI 1010 - 1035, API STD 5L G	6
API STD 5L Gr. B - API 5LX Gr. X-70	7
Carbon Equivalent Calculation	8

PRESS EITHER 1, 2, 3, 4, 5, 6, 7 OR 8 TO PROCEED TO THE DESIRED FUNCTIONS

1) From option 1, you will proceed to a narrative which outlines the usage of the chemistries library program.
2) From options 2-7, you will proceed to the desired chemistries which are arranged in numerical order.
3) From option 8, you will return to the carbon equivalent calculation and resume the program calculations.
4) By keying in "PREV" the previous screen will be redisplayed, by keying in "CC MENU" you will proceed to the chemical compositions menu and by keying in "Help MENU" you will proceed to the help menu. These commands should be keyed after the "Next screen?" prompt appears.

o. Consumable Weld Deposit Hydrogen Content

This is a narrative consisting of two screens which describe the relative hydrogen levels in weld metal deposited using the different types of electrodes and wleding processes. The user can return to the initial screen by using the "PREV" command and can return to the selection of scales segment of the program by hitting the "RETURN" button after receiving the appropriate prompt.

p. Preheating Considerations

This is a narrative consisting of one screen which describes certain points to be considered when applying preheat. By hitting "RETURN" the user will proceed to the help menu.

q. Fit-Up Considerations

This is a narrative consisting of one screen which describes the restrictions of fit-up such that the program can be applied to the users particular situation. By hitting "RETURN" the user will proceed to the help menu.

r. Solidification Cracking Considerations

This is a narrative consisting of two screens which describe the effects of having too high a heat input. The results of keying in the "PREV" command or hitting "RETURN" are a previously mentioned.

s. Notch Toughness Considerations

This is a narrative consisting of one screen which describes the effects of too high or too low a heat input. "RETURN" as previously mentioned.

t. Joint Restraint

This is a narrative consisting of one screen which describes the effects of restraint and applicability to the program. "RETURN" as previously mentioned.

u. Preheat Relaxations

This is a narrative consisting of one screen which describes the relaxations to the values obtained from the program which can be exercised under certain conditions. "RETURN" as previously mentioned.

v. Main Menu

By hitting the "RETURN" button after the "Next screen?" prompt, the user will proceed to the main menu.

APPENDIX B

SYSTEM MESSAGES

1. FUNCTION — OPTION

   C.E. Exceeds 0.53, program valid up to 0.53 only ....?Redo from start — (Y/N)

PRESS "Y" TO REINITIATE SCREEN AND CALCULATION OR "N" AND PROCEED TO MAIN MENU

2. FUNCTION — OPTION

   ?Redo from start — Key in correct entry

KEY IN CORRECT ENTRY NEXT TO THE PROMPT

3. FUNCTION — OPTION

   ?Incorrect input...?Redo from start — (Y/N)

PRESS "Y" TO REINITIATE SCREEN AND CALCULATION OR "N" TO PROCEED TO CALCUALATIONS MENU

4. FUNCTION — OPTION

   Key in either "Y" or "N" — (Y/N)

PRESS EITHER "Y" OR "N" TO INFORM COMPUTER THAT FILLET WELDS ARE DIRECTLY OPPOSED OR NOT. MESSAGE WILL RETURN CONTROL TO USER AFTER 4 SECONDS.

ACTION	RESULT
10. Type "0.3" next to "% Carbon" prompt "1.06" next to "% Manganese" prompt and hit "RETURN" after each. Rather than typing "0" after the other prompts, just hit "RETURN"	Calculation of C.E. = 0.48 for ASTM A106 Gr. B appears at bottom of screen.
11. Type "N" and hit "RETURN"	Next screen? prompt engaged.
12. Hit "RETURN"	Weld Deposit Hydrogen Content Screen engaged.
13. Hit "1" and "RETURN"	Select hydrogen content scale.
14. Hit "RETURN"	Type of Joint screen engaged.
15. Hit "1" and "RETURN"	Select fillet joint.
16. Hit "1" and "RETURN"	Select E7010 as electrode type.
17. Type in "33" next to the Arc Voltage prompt, "130" next to Welding Current prompt and "2" next to the Welding Speed prompt and hit "RETURN" after each.	Supply data for arc energy calculation.
18. Type in "N" and hit "RETURN"	Arc Energy = 1.43 kJ/mm answer obtained.
19. Hit "RETURN"	Combined Thickness Calculation screen engaged.
20. Type in "6.3" after T1, T2 and T3 prompts and hit "RETURN" after each.	Supply data for combined thickness calculation.

ACTION	RESULT
21. Type in "N" and hit "RETURN"	Engages Directly Opposed twin fillet welds prompt.
22. Type in "N" and hit "RETURN"	Engages Next Screen prompt.
23. Hit "RETURN"	Engages Recommended Preheat screen.

Data Presented:

1. All user inputs from previous screens with a minimum recommended preheat of 0 degrees celsius.

2.

Electrode Diameter (mm)	Recommended Run Length (mm)
2.5	95
3.2	150
4	235
5	370
6	535
6.3	590
8	955
10	0

This information provides a maximum electrode run length to achieve the user inputed arc energy for a given electrode diameter.

3.

Arc Energy (kJ/mm)	Minimum Single Run Leg Length (mm)
1.0	4
1.4	5
2.0	6
2.8	8
3.8	10
5.5	12

This information is only applicable to single run fillet welds. The table shows the user recommended arc energies for a given leg length. This table will not appear for butt welds.

APPENDIX C

```
10 REM INTERACTIVE AVOIDANCE OF HYDROGEN CRACKING PROBLEM
400 REM PRESENT INITIAL INTRODUCTORY SCREEN WITH PROGRAM TITLE
410     CLS:KEY OFF
420     LOCATE 5,30
430     PRINT "COMPUTER PROGRAM"
440     LOCATE 10,35
450     PRINT "FOR THE"
460     LOCATE 15,24
470     PRINT "AVOIDANCE OF HYDROGEN CRACKING"
480 REM TIMER OF 5 SEC THEN SHOW MENU SCREEN
490     FOR I = 1 TO 2500
500     X = X + I
510     NEXT I
520     CLS:SOUND 1000,1
530 REM MENU SCREEN DEFINITION
540     LOCATE 3,31
550     PRINT "MENU SELECTION"
560     LOCATE 7,8
570     PRINT "<1>  General description of hydrogen cracking."
580     LOCATE 9,8
590     PRINT "<2>  Conditions for the avoidance of hydrogen cracking.":PRINT
600     PRINT "       <3>  Calculation and explanation of variables for the avoi
dance of                   hydrogen cracking."
610     LOCATE 14,8
620     PRINT "<4>  Calculation of variables for the avoidance of hydrogen crack
ing."
630     LOCATE 16,8
640     PRINT "<5>  Help MENU."
650 REM MENU SELECTION
660     LOCATE 25,1
665     ON ERROR GOTO 6020
670     INPUT "MENU Selection";SEL
690     IF SEL <= 5 AND SEL >= 1 GOTO 700 ELSE ERROR 73
700     ON SEL GOSUB 1000,2000,3000,4000,5000
1000 REM DESCRIPTION OF GENERAL CONDITIONS OF HYDROGEN CRACKING
1020    CLS:SOUND 1000,1
1030    OPEN "I",#1,"HICC.BAS"
1040    FOR I = 1 TO 50
1050    INPUT #1,A$
1060    PRINT A$
1070    IF I = 20 THEN GOTO 1080 ELSE GOTO 1110
1080    LOCATE 25,1
1085    ON ERROR GOTO 6020
1090    INPUT "Next screen";S$
1093    IF INSTR(1,S$,"HELP") = 1 THEN CLOSE #1
1095    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
1100    IF LEN(S$) = 0 THEN GOTO 1105 ELSE ERROR 73
1105    CLS:SOUND 1000,1
1110    IF EOF(1) THEN GOTO 1130
1120    NEXT I
1130    CLOSE #1
1140    LOCATE 25,1
1145    ON ERROR GOTO 6020
1150    INPUT "Return to MENU";S$
1170    IF S$ = "PREV" THEN GOTO 1020
1175    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
1180    IF LEN(S$) = 0 THEN GOTO 520 ELSE ERROR 73
2000 REM DESCRITPION OF CONDITIONS FOR THE AVOIDANCE OF HYDROGEN CRACKING
2010    CLS:SOUND 1000,1
2020    OPEN "I",#2,"AVDHC.BAS"
```

```
2030    FOR I = 1 TO 60
2040    INPUT #2,AVD$
2050    PRINT AVD$
2060    IF I = 23 THEN GOTO 2070 ELSE GOTO 2100
2070    LOCATE 25,1
2075    ON ERROR GOTO 6020
2080    INPUT "Next screen";S$
2083    IF INSTR(1,S$,"HELP") = 1 THEN CLOSE #2
2085    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
2090    IF LEN(S$) = 0 THEN GOTO 2095 ELSE ERROR 73
2095    CLS:SOUND 1000,1
2100    IF EOF(2) THEN GOTO 2120
2110    NEXT I
2120    CLOSE #2
2130    LOCATE 25,1
2135    ON ERROR GOTO 6020
2140    INPUT "Return to MENU"; S$
2145    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
2160    IF S$ = "PREV" THEN GOTO 2010
2170    IF LEN(S$) = 0 THEN GOTO 520 ELSE ERROR 73
3000 REM SEQUENCE OF CALCULATIONS EXPLANATION & DEFINITION OF CARBON EQUIVALENT
3010    CLS:SOUND 1000,1
3020    OPEN "I",#3,"SEQCAL.BAS"
3030    FOR I = 1 TO 60
3040    INPUT #3,SEQ$
3050    PRINT SEQ$
3060    IF I = 23 THEN GOTO 3070 ELSE GOTO 3100
3070    LOCATE 25,1
3075    ON ERROR GOTO 6020
3080    INPUT "Next screen";S$
3081    IF INSTR(1,S$,"HELP") = 1 THEN CLOSE #3
3082    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
3090    IF LEN(S$) = 0 THEN GOTO 3095 ELSE ERROR 73
3095    CLS:SOUND 1000,1
3100    IF EOF(3) THEN GOTO 3120
3110    NEXT I
3120    CLOSE #3
3130    LOCATE 25,1
3135    ON ERROR GOTO 6020
3140    INPUT "Return to MENU";S$
3150    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
3160    IF S$ = "PREV" THEN GOTO 3010
3180    IF LEN(S$) = 0 THEN GOTO 520 ELSE ERROR 73
4000 REM CALCULATIONS MENU
4010    CLS:SOUND 1000,1:LOCATE 3,30:PRINT "CALCULATIONS MENU"
4020    LOCATE 6,8: PRINT "<1>    Sequence of Calculations."
4030    LOCATE 8,8: PRINT "<2>    Carbon Equivalent Definition."
4040    LOCATE 10,8: PRINT "<3>    Carbon Equivalent Calculation."
4050    LOCATE 12,8:PRINT "<4>    Weld Deposit Hydrogen Content."
4060    LOCATE 14,8:PRINT "<5>    Type of Joint."
4070    LOCATE 16,8:PRINT "<6>    Arc Energy Calculation."
4080    LOCATE 18,8:PRINT "<7>    Combined Thickness Calculation."
4090    LOCATE 20,8:PRINT "<8>    Recommended Preheat."
4095    ON ERROR GOTO 6020
4100    LOCATE 25,1:INPUT "MENU Selection";SEL
4105    IF SEL <= 8 AND SEL >= 1 THEN GOTO 4108 ELSE ERROR 73
4108    CLS:SOUND 1000,1
4110    ON SEL GOTO 3020,4210,4302,4400,4500,4600,4700,4800:GOTO 4210
4200 REM CARBON EQUIVALENT DEFINITION
4205    CLS:SOUND 1000,1
```

```
4210     OPEN "I",#4,"CEDEF.BAS"
4215     FOR I = 1 TO 50
4220     INPUT #4,CEF$
4225     PRINT CEF$
4230     IF I = 25 THEN GOTO 4235 ELSE GOTO 4250
4235     LOCATE 25,1
4237     ON ERROR GOTO 6020
4240     INPUT "Next screen";S$
4242     IF INSTR(1,S$,"HELP") = 1 THEN CLOSE #4
4244     IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
4245     IF LEN(S$) = 0 THEN GOTO 4247 ELSE ERROR 73
4247     CLS:SOUND 1000,1
4250     IF EOF(4) THEN GOTO 4260
4255     NEXT I
4260     CLOSE #4
4265     LOCATE 25,1
4267     ON ERROR GOTO 6020
4270     INPUT "Return to MENU";S$
4272     IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
4275     IF S$ = "PREV" THEN GOTO 4200
4280     IF LEN(S$) = 0 THEN GOTO 4010 ELSE ERROR 73
4285     CLS:SOUND 1000,1
4300 REM USER CARBON EQUIVALENT CALCULATION BY LADLE ANALYSIS
4302     LOCATE 2,24
4304     PRINT "CARBON EQUIVALENT CALCULATION"
4306     LOCATE 5,1
4308     INPUT "Do you have the parent plate ladle analysis/mill test certificate
s (Y/N)";AN$
4310     LET H = INSTR(1,AN$,"HELP"):IF H <> 0 THEN GOTO 5000
4311     ON ERROR GOTO 6100
4312     IF AN$ <> "Y" AND AN$ <> "N" THEN ERROR 74
4314     IF AN$ = "Y" THEN GOTO 4316 ELSE GOTO 5000
4316     LOCATE 8,1
4318     PRINT "Key in the %composition for each alloying element, then press RET
URN after each entry until all the %compositions are keyed in. Press RETURN agai
n for the Car- bon Equivalent (C.E.)."
4320     PRINT:
4322     INPUT "ASTM, AISI OR API Designation";NBR$:PRINT
4324     INPUT "% CARBON";C
4326     INPUT "% MANAGANESE";MN
4328     INPUT "% CHROMIUM";CR
4330     INPUT "% MOLYBDENUM";MO
4332     INPUT "% VANADIUM";V
4334     INPUT "% NICKEL";NI
4336     INPUT "% COPPER";CU
4337     INPUT "?Redo from start (Y/N) ",S$:IF S$ = "Y" GOTO 4285
4338     PRINT
4340     C.E. = C + MN/6 + (CR + MO + V)/5 + (NI + CU)/15
4342     IF C.E. > .53 THEN GOTO 6010
4344     PRINT USING "The Carbon Equivalent is #.##";C.E.:PRINT "for ";NBR$;".";
4345     ON ERROR GOTO 6020
4346     LOCATE 25,1:INPUT "Next screen";S$
4347     IF INSTR(1,S$,"HELP") = 1 GOTO 5000
4348     IF LEN(S$) = 0 THEN GOTO 4349 ELSE ERROR 73
4349     CLS:SOUND 1000,1
4400 REM SELECTION OF SCALES
4410     LOCATE 3,8:PRINT "CONSUMABLE CLASSIFICATION BY WELD DEPOSIT HYDROGEN CON
TENT"
4420     LOCATE 6,8:PRINT "The following scales should be used under conditions o
f normal fit for consum-  ables which give weld deposit hydrogen contents of:"
```

```
4430    PRINT:PRINT "       <1>    more than 15 ml/100 g metal (Exx10 to 14,
                                   Exx20, Exx24, Exx27, Exx28, Exx30)"
4440    PRINT:PRINT"        <2>    not more than 15 ml/100 g metal but more than
                                   10 ml/100 g metal (Exx15,  Exx16, Exx18)"
4450    PRINT:PRINT"        <3>    not more than 10 ml/100 g metal but more than
                                   5 ml/100 g metal (GMAW ExxS-1 to 6)"
4460    LOCATE 19,8:PRINT "<4>     not more than 5 ml/100 g metal (Suitable GTAW
electrodes)"
4470    LOCATE 21,8:PRINT "<5>     FCAW, SAW and appropriate drying treatments -
see Help MENU <2>"
4475    ON ERROR GOTO 6020
4480    LOCATE 25,1:INPUT "MENU Selection";SELC
4485    IF SELC <= 5 AND SELC >= 1 THEN GOTO 4490 ELSE ERROR 73
4490    CLS:SOUND 1000,1:IF SELC = 5 THEN GOTO 5010 ELSE GOTO 4500
4500 REM SELECT FILLET OR BUTT WELD
4505    LOCATE 3,31:PRINT "TYPE OF JOINT"
4510    LOCATE 8,31:PRINT "<1>    Fillet"
4515    LOCATE 10,31:PRINT "<2>    Butt"
4517    ON ERROR GOTO 6020
4520    LOCATE 13,1:INPUT "Type of Joint";W
4522    IF W >= 1 AND W <= 2 THEN GOTO 4525 ELSE ERROR 73
4525    IF SELC >= 1 OR SELC <= 4 THEN GOTO 4530 ELSE GOTO 4565
4530    LOCATE 16,1:PRINT "Which of the following SMAW electrodes is being used?
"
4535    PRINT:LOCATE 18,31:PRINT "<1>    Exx10, Exx12, Exx13 or Exx15"
4540    LOCATE 19,31:PRINT "<2>    Exx14 or Exx18"
4545    LOCATE 20,31:PRINT "<3>    Exx24"
4550    LOCATE 21,31:PRINT "<4>    Exx28"
4555    LOCATE 22,31:PRINT "<5>    None of the above listed."
4557    ON ERROR GOTO 6020
4560    LOCATE 20,1:INPUT "Number";REN
4562    IF REN >= 1 AND REN <= 5 THEN GOTO 4565 ELSE ERROR 73
4565    LOCATE 25,1:INPUT "Next screen";S$
4567    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
4570    IF LEN(S$) = 0 THEN GOTO 4575 ELSE ERROR 73
4575    CLS:SOUND 1000,1
4600 REM ARC ENERGY CALCULATION
4605    OPEN "I",#7,"AE.BAS"
4610    FOR I = 1 TO 21
4615    INPUT #7, AE$
4620    PRINT AE$
4625    IF EOF(7) THEN CLOSE #7 ELSE NEXT I
4630    LOCATE 19,1:INPUT "Arc voltage";AV:INPUT "Welding current";WC:INPUT "Wel
ding speed (mm/sec)";WS
4632    INPUT "?Redo from start (Y/N) ",S$
4633    IF S$ = "Y" THEN GOTO 4644 ELSE GOTO 4635
4635    LET AE = (AV * WC)/(WS * 1000)
4640    PRINT USING "The Arc Energy is #.## kJ/mm.";AE:GOTO 4645
4644    CLS:SOUND 1000,1:GOTO 4600
4645    LOCATE 25,1:INPUT "Next screen";S$
4647    IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
4650    IF LEN(S$) = 0 THEN GOTO 4655 ELSE ERROR 73
4655    CLS:SOUND 1000,1
4700 REM COMBINED THICKNESS CALCULATION
4705    OPEN "I",#8,"CT.BAS"
4710    FOR I = 1 TO 20
4715    INPUT #8,CT$
4720    PRINT CT$
4725    IF EOF(8) THEN CLOSE ELSE NEXT I
4730    LOCATE 15,1:INPUT "T1";T1:INPUT "T2";T2
```

```
4731     IF W = 1 THEN INPUT "T3";T3
4732     INPUT "?Redo from start (Y/N) ",S$
4733     IF S$ = "Y" THEN GOTO 4655 ELSE GOTO 4734
4734     IF J = 2 GOTO 4755
4735     IF W = 1 THEN LOCATE 18,1:INPUT "Directly opposed twin fillet welds (Y/N
";DOP$
4740     IF DOP$ = "N" THEN GOTO 4755
4745     IF DOP$ = "Y" THEN GOTO 4760 ELSE GOTO 4750
4750     LOCATE 1,1:PRINT "Key in either 'Y' or 'N'":FOR I = 1 TO 2000:X = X + 1:
NEXT I:CLS :SOUND 1000,1:GOTO 4700
4755     LET CT = T1 + T2 + T3:GOTO 4765
4760     LET CT = 1/2*(T1 + T2 + T3)
4765     PRINT:PRINT "The Combined thickness is ";CT;" mm."
4770     LOCATE 25,1:INPUT "Next screen";S$:CLS:SOUND 1000,1
4775     IF LEN(S$) = 0 THEN GOTO 4800 ELSE IF S$ = "PREV" GOTO 4600
4800 REM RECOMMENDED PREHEAT CALCULATION
4805     OPEN "R",#1,"GRAPHS.BAS"
4810     FIELD #1, 4 AS LPHT$, 4 AS C$, 4 AS A1$, 4 AS A0$
4815     SUM = INT(100*(SELC + C.E.))/100
4820     IF SUM <= 1.37 OR SUM <= 2.39 OR SUM <= 3.4 OR SUM <= 4.45 THEN CODE% =
10
4825     IF SUM = 1.38 OR SUM = 2.4 OR SUM = 3.41 OR SUM = 4.46 THEN CODE% = 20
4830     IF SUM = 1.39 OR SUM = 2.41 OR SUM = 3.42 OR SUM = 3.43 OR SUM = 4.47 OR
 SUM = 4.48 THEN CODE% = 30
4835     IF SUM = 1.4 OR SUM = 2.42 OR SUM = 3.44 OR SUM = 4.49 THEN CODE% = 40
4840     IF SUM = 1.41 OR SUM = 2.43 OR SUM = 3.45 OR SUM = 4.5 THEN CODE% = 50
4845     IF SUM = 1.42 OR SUM = 2.44 OR SUM = 3.46 OR SUM = 4.51 THEN CODE% = 60
4850     IF SUM = 1.43 OR SUM = 2.45 OR SUM = 3.47 OR SUM = 4.52 THEN CODE% = 70
4855     IF SUM = 1.44 OR SUM = 1.45 OR SUM = 2.46 OR SUM = 2.47 OR SUM = 3.48 OR
 SUM = 3.49 OR SUM = 4.53 THEN CODE% = 80
4860     IF SUM = 1.46 OR SUM = 1.47 OR SUM = 2.48 OR SUM = 2.49 OR SUM = 3.5 OR
SUM = 3.51 THEN CODE% = 90
4865     IF SUM = 1.48 OR SUM = 1.49 OR SUM = 2.5 OR SUM = 2.51 OR SUM = 3.52 OR
SUM = 3.53 THEN CODE% = 100
4870     IF SUM = 1.5 OR SUM = 1.51 OR SUM = 2.52 OR SUM = 2.53 THEN CODE% = 110
4875     IF SUM = 1.52 OR SUM = 1.53 THEN CODE% = 120
4880     GET #1, CODE%
4885     IF AE >= CVS(C$) THEN AF = 1 ELSE AF = 0
4890     LET AEI = CVS(A1$)*CT + CVS(A0$)
4895     LET AEF = AEI - (AF*AEI) + (AF*CVS(C$))
4900     IF AE >= AEF THEN PHT = CVS(LPHT$) ELSE GOTO 4940
4905     LOCATE 2,23:PRINT "RECOMMENDED PREHEAT CALCULATION":PRINT:PRINT:
4910     PRINT USING "The Recommended Preheat is ###.# deg. C";PHT:PRINT:
4915     PRINT USING "The Carbon Equivalent = #.##";C.E.
4920     PRINT "The Scale was Number #";SELC
4925     IF W = 1 THEN PRINT "The Type of Weld was a FILLET" ELSE PRINT "The Type
 of Weld was a BUTT"
4930     PRINT USING "The Arc Energy was #.## kJ/mm";AE
4935     PRINT USING "The Combined Thickness was ###.# mm";CT
4937     IF REN <= 4 THEN GOTO 4950 ELSE GOTO 4980
4940     LET CODE% = CODE% + 1
4945     GOTO 4880
4950     GOTO 7000
4970     ON ERROR GOTO 6020
4975     LOCATE 25,1:INPUT "Main MENU";S$:CLOSE
4977     IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
4980     IF S$ = "PREV" THEN GOTO 4655
4985     IF LEN(S$) = 0 THEN GOTO 520 ELSE ERROR = 73
4990     IF INSTR(1,S$,"HELP") THEN GOTO 5000
5000 REM HELP MENU
```

```
5005    CLS:KEY OFF:SOUND 1000,1
5010    LOCATE 3,34:PRINT "HELP MENU"
5015    LOCATE 6,8:PRINT  "<1>   Chemical Compositions for Carbon and Carbon Mang
anese Steels."
5020    LOCATE 8,8:PRINT  "<2>   Consumable Weld Deposit Hydrogen Content."
5025    LOCATE 10,8:PRINT "<3>   Preheating Considerations."
5030    LOCATE 12,8:PRINT "<4>   Fit-Up Considerations."
5035    LOCATE 14,8:PRINT "<5>   Solidification Cracking Considerations."
5040    LOCATE 16,8:PRINT "<6>   Notch Toughness Considerations."
5045    LOCATE 18,8:PRINT "<7>   Joint Restraint."
5050    LOCATE 20,8:PRINT "<8>   Preheat Relaxations."
5055     LOCATE 22,8:PRINT "<9>   Main MENU."
5057     ON ERROR GOTO 6020
5060     LOCATE 25,1:INPUT "MENU Selection";SEL
5062     IF SEL >= 1 AND SEL <= 9 THEN GOTO 5065 ELSE ERROR 73
5065     ON SEL GOSUB 5100,5200,5300,5400,5500,5600,5700,5800,520
5099 REM SELEC
5100    CLS:SOUND 1000,1
5101    LOCATE 3,4:PRINT "     CHEMICAL COMPOSITIONS FOR CARBON AND CARBON MANGANE
SE STEELS MENU"
5102    LOCATE 6,8:PRINT "<1>     Explanatory Notes"
5103    LOCATE 8,8:PRINT "<2>     ASTM A27 - A135 Gr. B"
5104    LOCATE 10,8:PRINT "<3>     ASTM A139 Gr. B - A334 Cl. 6"
5105    LOCATE 12,8:PRINT "<4>     ASTM A350 - A516 Gr. 70"
5106    LOCATE 14,8:PRINT "<5>     ASTM A524 Typ. I - A737 Gr. B"
5107    LOCATE 16,8:PRINT "<6>     ASTM A737 Gr. C, AISI 1010 - 1035, API STD 5L G
r. A"
5108    LOCATE 18,8:PRINT "<7>     API STD 5L Gr. B - API 5LX Gr. X-70"
5109    LOCATE 20,8:PRINT "<8>     Carbon Equivalent Calculation":ON ERROR GOTO 60
20
5110    LOCATE 25,1:INPUT "MENU Selection";SEL
5111    IF SEL >= 1 AND SEL <= 8 THEN GOTO 5112 ELSE ERROR 73
5112    CLS:SOUND 1000,1:ON SEL GOSUB 5135,5137,5141,5145,5149,5153,5157,4316
5113    OPEN "I",#5,"CECCM.BAS"
5114    FOR I = 1 TO N
5115    INPUT #5,CEX$
5116    IF I >= M AND I <= N THEN PRINT CEX$ :IF EOF(5) GOTO 5118
5117    NEXT I
5118    CLOSE #5 : LOCATE 25,1
5119    INPUT "Next screen";S$:CLS:SOUND 1000,1
5120    IF S$ = "HELP" GOTO 5010
5121    IF S$ = "CC MENU" GOTO 5101
5122    IF M=1 GOTO 5136
5123    IF M=21 GOTO 5138
5124    IF M=43 GOTO 5140
5125    IF M=65 GOTO 5142
5126    IF M=87 GOTO 5144
5127    IF M=109 GOTO 5146
5128    IF M=131 GOTO 5148
5129    IF M=153 GOTO 5150
5130    IF M=175 GOTO 5152
5131    IF M=197 GOTO 5154
5132    IF M=219 GOTO 5156
5133    IF M=241 GOTO 5158
5134    IF M=263 GOTO 11147
5135    LET M = 1:LET N = 20:GOTO 5113
5136    IF LEN(S$) = 0 THEN GOTO 5137 ELSE IF S$ = "PREV" GOTO 5102
5137    LET M = 21:LET N = 42:GOTO 5113
5138    IF LEN(S$) = 0 THEN GOTO 5139 ELSE IF S$ = "PREV" GOTO 5135
5139    LET M = 43:LET N = 64:GOTO 5113
```

```
5140    IF LEN(S$) = 0 THEN GOTO 5141 ELSE IF S$ = "PREV" GOTO 5137
5141    LET M = 65:LET N = 86:GOTO 5113
5142    IF LEN(S$) = 0 THEN GOTO 5143 ELSE IF S$ = "PREV" GOTO 5139
5143    LET M = 87:LET N = 108:GOTO 5113
5144    IF LEN(S$) = 0 THEN GOTO 5145 ELSE IF S$ = "PREV" GOTO 5141
5145    LET M = 109:LET N = 130:GOTO 5113
5146    IF LEN(S$) = 0 THEN GOTO 5147 ELSE IF S$ = "PREV" GOTO 5143
5147    LET M = 131:LET N = 152:GOTO 5113
5148    IF LEN(S$) = 0 THEN GOTO 5149 ELSE IF S$ = "PREV" GOTO 5145
5149    LET M = 153:LET N = 174:GOTO 5113
5150    IF LEN(S$) = 0 THEN GOTO 5151 ELSE IF S$ = "PREV" GOTO 5147
5151    LET M = 175:LET N = 196:GOTO 5113
5152    IF LEN(S$) = 0 THEN GOTO 5153 ELSE IF S$ = "PREV" GOTO 5149
5153    LET M = 197:LET N = 218:GOTO 5113
5154    IF LEN(S$) = 0 THEN GOTO 5155 ELSE IF S$ = "PREV" GOTO 5151
5155    LET M = 219:LET N = 240:GOTO 5113
5156    IF LEN(S$) = 0 THEN GOTO 5157 ELSE IF S$ = "PREV" GOTO 5153
5157    LET M = 241:LET N = 262:GOTO 5113
5158    IF LEN(S$) = 0 THEN GOTO 5102 ELSE IF S$ = "PREV" GOTO 5155
5200 REM CONSUMABLE WELD DEPOSIT HYDROGEN CONTENT
5205    CLS:SOUND 1000,1
5210    OPEN "I", #9, "CWDHC.BAS"
5215    FOR I = 1 TO 40
5220    INPUT #9, CWD$
5225    PRINT CWD$
5230    IF I = 21 THEN GOTO 5235 ELSE GOTO 5260
5235    LOCATE 25,1
5240    ON ERROR GOTO 6020
5245    INPUT "Next screen";S$
5250    IF LEN(S$) = 0 THEN GOTO 5255 ELSE ERROR 73
5255    CLS:SOUND 1000,1
5260    IF EOF(9) THEN GOTO 5270
5265    NEXT I
5270    CLOSE #9
5275    LOCATE 25,1
5280    ON ERROR GOTO 6020
5285    INPUT "Return to SELECTION OF SCALES";S$
5290    IF S$ = "PREV" THEN GOTO 5205
5295    IF LEN(S$) = 0 THEN GOTO 4349 ELSE ERROR 73
5300 REM PREHEATING CONSIDERATIONS
5303    CLS:SOUND 1000,1
5305    OPEN "I", #10, "PHCONSID.BAS"
5310    FOR I = 1 TO 30
5313    INPUT #10, PHC$
5315    PRINT PHC$
5350    IF EOF(10) THEN GOTO 5360
5355    NEXT I
5360    CLOSE #10
5365    LOCATE 25,1
5370    ON ERROR GOTO 6020
5375    INPUT "Return to MENU";S$
5380    IF LEN(S$) = 0 THEN GOTO 5000 ELSE ERROR 73
5400 REM FIT-UP CONSIDERATIONS
5405    CLS:SOUND 1000,1
5410    OPEN "I", #11, "FUCONSID.BAS"
5415    FOR I = 1 TO 15
5420    INPUT #11, FUC$
5425    PRINT FUC$
5430    IF EOF(11) THEN GOTO 5440
5435    NEXT I
```

```
5440     CLOSE #11
5445     LOCATE 25,1
5450     ON ERROR GOTO 6020
5455     INPUT "Return to MENU";S$
5460     IF LEN(S$) = 0 THEN GOTO 5000 ELSE ERROR 73
5500 REM SOLIDIFICATION CRACKING DEFINITION
5503     CLS:SOUND 1000,1
5505    OPEN "I",#6,"SOLC.BAS"
5510    FOR I = 1 TO 60
5515    INPUT #6,SOL$
5520    PRINT SOL$
5525    IF I = 25 THEN GOTO 5530 ELSE GOTO 5545
5530    LOCATE 25,1
5535    INPUT "Next screen";S$:SOUND 1000,1:CLS
5540    IF LEN(S$) = 0 THEN GOTO 5545
5545    IF EOF(6) THEN GOTO 5555
5550    NEXT I
5555    CLOSE #6
5560    LOCATE 25,1
5565    INPUT "Return to Help MENU";S$
5570    IF S$ = "PREV" THEN  GOTO 5500
5575    IF LEN(S$) = 0 THEN GOTO 5005
5600 REM NOTCH TOUGHNESS CONSIDERATIONS
5605     CLS:SOUND 1000,1
5610     OPEN "I", #12, "NOTCHCON.BAS"
5615     FOR I = 1 TO 20
5620     INPUT #12, NTC$
5625     PRINT NTC$
5630     IF EOF(12) THEN GOTO 5640
5635     NEXT I
5640     CLOSE #12
5645     LOCATE 25,1
5650     ON ERROR GOTO 6020
5655     INPUT "Return to MENU";S$
5660     IF LEN(S$) = 0 THEN GOTO 5000 ELSE ERROR 73
5700 REM JOINT RESTRAINT
5705     CLS:SOUND 1000,1
5710     OPEN "I", #13, "JOINTRES.BAS"
5715     FOR I = 1 TO 15
5720     INPUT #13, JR$
5725     PRINT JR$
5730     IF EOF(13) THEN GOTO 5740
5735     NEXT I
5740     CLOSE #13
5745     LOCATE 25,1
5750     ON ERROR GOTO 6020
5755     INPUT "Return to MENU";S$
5760     IF LEN(S$) = 0 THEN GOTO 5000 ELSE ERROR 73
5800 REM PREHEAT RELAXATIONS
5805     CLS:SOUND 1000,1
5810     OPEN "I", #14, "PHRELAXN.BAS"
5815     FOR I = 1 TO 25
5820     INPUT #14, PHR$
5825     PRINT PHR$
5830     IF EOF(14) THEN GOTO 5840
5835     NEXT I
5840     CLOSE #14
5845     LOCATE 25,1
5850     ON ERROR GOTO 6020
5855     INPUT "Return to MENU";S$
```

```
5860     IF LEN(S$) = 0 THEN GOTO 5000 ELSE ERROR 73
6000 REM ERROR TRAPPING
6010     CLS:SOUND 1000,1
6012     PRINT "C.E. Exceeds 0.53, program valid up to 0.53 only."
6014     PRINT:INPUT "?Redo from start  ",S$
6016     IF S$ = "Y" THEN GOTO 4285 ELSE GOTO 520
6020     IF ERR = 73 THEN PRINT "?Redo from start"
6021     IF ERL = 690 THEN RESUME 670
6022     IF ERL = 4105 THEN RESUME 4100
6023     IF ERL = 4485 THEN RESUME 4480
6024     IF ERL = 4522 THEN RESUME 4517
6025     IF ERL = 4562 THEN RESUME 4560
6026     IF ERL = 4631 THEN RESUME 4630
6027     IF ERL = 4632 THEN RESUME 4630
6028     IF ERL = 4633 THEN RESUME 4630
6029     IF ERL = 5062 THEN RESUME 5060
6030     IF ERL = 5111 THEN RESUME 5110
6031     IF ERL = 1100 THEN RESUME 1080
6032     IF ERL = 1180 THEN RESUME 1140
6033     IF ERL = 2090 THEN RESUME 2070
6034     IF ERL = 2170 THEN RESUME 2130
6035     IF ERL = 3090 THEN RESUME 3070
6036     IF ERL = 3180 THEN RESUME 3130
6037     IF ERL = 4245 THEN RESUME 4235
6038     IF ERL = 4280 THEN RESUME 4265
6040     IF ERL = 4348 THEN RESUME 4345
6041     IF ERL = 4570 THEN RESUME 4565
6042     IF ERL = 4650 THEN RESUME 4645
6043     IF ERL = 7385 THEN RESUME 7377
6044     IF ERL = 4985 THEN RESUME 4970
6045     IF ERL = 5062 THEN RESUME 5057
6046     IF ERL = 5111 THEN RESUME 5110
6047     IF ERL = 5250 THEN RESUME 5235
6048     IF ERL = 5295 THEN RESUME 5275
6049     IF ERL = 5380 THEN RESUME 5365
6050     IF ERL = 5460 THEN RESUME 5445
6051     IF ERL = 5660 THEN RESUME 5645
6052     IF ERL = 5760 THEN RESUME 5745
6100     PRINT:IF ERR = 74 THEN PRINT "?Incorrect input":PRINT
6102     INPUT "?Redo from start ",S$
6104     IF S$ = "Y" THEN GOTO 6106 ELSE GOTO 4000
6106     IF ERL = 4312 THEN RESUME 4285
7000 REM SELECTION OF ELECTRODE DIAMETER AND RUNLENGTH AND MINIMUM SUGGESTED LEG
  LENGTH FOR FILLET WELDS
7005     IF W = 1 THEN GOTO 7010 ELSE GOTO 7520
7010     IF REN = 1 THEN OPEN "R", #2, "TABLE6A.BAS" ELSE GOTO 7140
7015     FIELD #2, 4 AS D1$, 4 AS R1$, 4 AS D2$, 4 AS R2$, 4 AS D3$, 4 AS R3$, 4
 AS D4$, 4 AS R4$, 4 AS D5$, 4 AS R5$, 4 AS D6$, 4 AS R6$, 4 AS D7$, 4 AS R7$, 4
 AS D8$, 4 AS R8$
7020     IF AE <= 2.2 THEN GOTO 7025 ELSE GOTO 7050
7025     LET CODE% = INT(AE*10)
7030     GET #2,CODE%
7035     IF CVS(D1$) >= 2.5 THEN GOTO 7075
7040     LET AE = AE + .1
7045     GOTO 7025
7050     LET CODE% = INT(AE*10)
7055     GET #2,CODE%
7060     IF CVS(D1$) >= 2.5 THEN GOTO 7075
7065     LET AE = AE + .1
7070     GOTO 7050
```

```
7075     PRINT "Electrode Diameter (mm)","Recommended Run Length (mm)"
7085     PRINT CVS(D1$) TAB(29) CVS(R1$)
7090     PRINT CVS(D2$) TAB(29) CVS(R2$)
7095     PRINT CVS(D3$) TAB(29) CVS(R3$)
7100     PRINT CVS(D4$) TAB(29) CVS(R4$)
7105     PRINT CVS(D5$) TAB(29) CVS(R5$)
7110     PRINT CVS(D6$) TAB(29) CVS(R6$)
7115     PRINT CVS(D7$) TAB(29) CVS(R7$)
7120     PRINT CVS(D8$) TAB(29) CVS(R8$)
7130     CLOSE:IF W = 2 THEN GOTO 4970 ELSE GOTO 7380
7140     IF REN = 2 THEN OPEN "R", #3, "TABLE6B.BAS" ELSE GOTO 7260
7150     FIELD #3, 4 AS D1$, 4 AS R1$, 4 AS D2$, 4 AS R2$, 4 AS D3$, 4 AS R3$, 4
AS D4$, 4 AS R4$, 4 AS D5$, 4 AS R5$, 4 AS D6$, 4 AS R6$, 4 AS D7$, 4 AS R7$, 4
AS D8$, 4 AS R8$
7155     IF AE <= 2.2 THEN GOTO 7160 ELSE GOTO 7185
7160     LET CODE% = INT(AE*10)
7165     GET #3,CODE%
7170     IF CVS(D1$) >= 2.5 THEN GOTO 7210
7175     LET AE = AE + .1
7180     GOTO 7160
7185     LET CODE% = INT(AE*10)
7190     GET #3, CODE%
7195     IF CVS(D1$) >= 2.5 THEN GOTO 7210
7200     LET AE = AE + .1
7205     GOTO 7185
7210     PRINT "Electrode Diameter (mm)","Recommended Run Length (mm)"
7215     PRINT CVS(D1$) TAB(29) CVS(R1$)
7220     PRINT CVS(D2$) TAB(29) CVS(R2$)
7225     PRINT CVS(D3$) TAB(29) CVS(R3$)
7230     PRINT CVS(D4$) TAB(29) CVS(R4$)
7235     PRINT CVS(D5$) TAB(29) CVS(R5$)
7240     PRINT CVS(D6$) TAB(29) CVS(R6$)
7245     PRINT CVS(D7$) TAB(29) CVS(R7$)
7250     PRINT CVS(D8$) TAB(29) CVS(R8$)
7255     CLOSE:IF W = 2 THEN GOTO 4970 ELSE GOTO 7380
7260     IF REN = 3 OR REN = 4 THEN OPEN "R", #4, "TABLE6C.BAS"
7265     FIELD #4, 4 AS D1$, 4 AS R1$, 4 AS D2$, 4 AS R2$, 4 AS D3$, 4 AS R3$, 4
AS D4$, 4 AS R4$, 4 AS D5$, 4 AS R5$, 4 AS D6$, 4 AS R6$, 4 AS D7$, 4 AS R7$, 4
AS D8$, 4 AS R8$
7270     IF AE <= 2.2 THEN GOTO 7275 ELSE GOTO 7300
7275     LET CODE% = INT(AE*10)
7280     GET #4, CODE%
7285     IF CVS(D1$) >= 2.5 THEN GOTO 7325
7290     LET AE = AE + .1
7295     GOTO 7275
7300     LET CODE% = INT(AE*10)
7305     GET #4, CODE%
7310     IF CVS(D1$) >= 2.5 THEN GOTO 7325
7315     LET AE = AE + .1
7320     GOTO 7300
7325     PRINT "Electrode Diameter (mm)", "Recommended Run Length (mm)"
7330     PRINT CVS(D1$) TAB(29) CVS(R1$)
7335     PRINT CVS(D2$) TAB(29) CVS(R2$)
7340     PRINT CVS(D3$) TAB(29) CVS(R3$)
7345     PRINT CVS(D4$) TAB(29) CVS(R4$)
7350     PRINT CVS(D5$) TAB(29) CVS(R5$)
7355     PRINT CVS(D6$) TAB(29) CVS(R6$)
7360     PRINT CVS(D7$) TAB(29) CVS(R7$)
7365     PRINT CVS(D8$) TAB(29) CVS(R8$)
7370     CLOSE:IF W = 2 THEN GOTO 4970 ELSE GOTO 7380
```

```
7377     ON ERROR GOTO 6020
7380     LOCATE 25,1:INPUT "Next screen";S$
7382     IF INSTR(1,S$,"HELP") = 1 THEN GOTO 5000
7384     IF S$ = "PREV" THEN GOTO 4655
7385     IF LEN(S$) = 0 THEN GOTO 7390 ELSE ERROR = 73
7390     CLS:SOUND 1000,1
7395     OPEN "R", #5, "TABLE7.BAS"
7400     FIELD #5, 4 AS AE1$, 4 AS ML1$, 4 AS AE2$, 4 AS ML2$, 4 AS AE3$, 4 AS ML
$, 4 AS AE4$, 4 AS ML4$, 4 AS AE5$, 4 AS ML5$, 4 AS AE6$, 4 AS ML6$
7405     LET CODE% = REN
7420     GET #5, CODE%
7425     LOCATE 3,17:PRINT "ARC ENERGY VALUES FOR SINGLE RUN FILLET WELDS"
7430     LOCATE 5,15:PRINT "(Valid for Exx12, Exx13, Exx15, Exx18 and Exx24.)"
7435     LOCATE 8,51:PRINT "Minimum Single Run"
7440     LOCATE 9,53:PRINT "Leg Length (mm)"
7445     LOCATE 8,11:PRINT "Arc Energy (kJ/mm)"
7450     LOCATE 10,12:PRINT USING "#.#";CVS(AE1$)
7455     LOCATE 10,58:PRINT CVS(ML1$)
7460     LOCATE 11,12:PRINT USING "#.#";CVS(AE2$):LOCATE 11,58:PRINT CVS(ML2$)
7465     LOCATE 13,12:PRINT USING "#.#";CVS(AE4$):LOCATE 13,58:PRINT CVS(ML4$)
7470     LOCATE 12,12:PRINT USING "#.#";CVS(AE3$):LOCATE 12,58:PRINT CVS(ML3$)
7475     LOCATE 13,12:PRINT USING "#.#";CVS(AE4$):LOCATE 13,58:PRINT CVS(ML4$)
7480     LOCATE 13,12:PRINT USING "#.#";CVS(AE4$):LOCATE 13,58:PRINT CVS(ML4$)
7490     LOCATE 14,12:PRINT USING "#.#";CVS(AE5$):LOCATE 14,57:PRINT CVS(ML5$)
7500     LOCATE 15,12:PRINT USING "#.#";CVS(AE6$):LOCATE 15,57:PRINT CVS(ML6$)
7510     CLOSE:GOTO 4970
7520     IF W = 2 THEN GOTO 7010
8000 REM DATA SEGMENT
```

POOR

QUALITY

ORIGINAL